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Ichthyofauna of the Reserva Biológica Guaribas and surrounding areas, state of Paraíba, Brazil

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Abstract
The removal and management of the Atlantic Forest over the past centuries caused the destruction of most of this ecosystem. Among the few remaining areas of Atlantic Forest north of the São Francisco River is the Reserva Biológica (REBIO) Guaribas. This study inventoried the ichthyofauna of the REBIO Guaribas (Mamanguape, Paraíba) and its surroundings. Two streams were sampled bimonthly (1 within the REBIO and the other adjacent to it) and another 11 additional sites were sampled once, resulting in 18 species of fish (7 families and 7 orders). Characiformes was the most representative order, with12 species. This species list is an important tool for impact assessments as well as conservation and management plans, given the current state of knowledge about Brazilian rivers and streams, especially those of the northeastern Atlantic Forest.

Key words
Fish; Atlantic Forest; Camaratuba River; conservation.

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Introduction

The Brazilian Atlantic Forest has been recognized as one of the major "hotspots" for biodiversity conservation, given its threatened state (it has been reduced by approximately 90% of the original area) associated with high rates of endemism (Myers et al. 2000, Ribeiro et al. 2009, Mittermeier et al. 2011). Efforts are being made to preserve what is remaining of this ecosystem and it has been recognized that, besides raising awareness and incentives to conservation, it is needed to gather meaningful information on species status in order to identify the specific causes of loss of biodiversity and to implement efficient conservation strategies (Galindo-Leal and Câmara 2005).

Efforts for the creation of protected areas are frequently justified based on their flora and on occurrence and distribution of terrestrial vertebrates, whereas the streams and their inhabiting organisms are often overlooked (Malabarba 2006).

The importance of inventories of fish in protected areas has been demonstrated in several studies (Cetra et al. 2010, Santos and Esteves 2014) and it has been argued that these relatively small units are representative of larger areas (Agostinho et al. 2004). Within this context,

the assessment of fish diversity in Atlantic Forest conservation units and the understanding of fish distribution in these areas becomes of chief concern for the appropriate management of freshwater ecosystems. Numbers of fish reported in the literature for the Atlantic Forest vary around 300 species, approximately 80% of those being endemic and 15% endangered (e.g. Menezes et al. 2007, Cetra et al. 2010, Abilhoa et al. 2011). These numbers reflect the environmental complexity of Atlantic Forest streams, as well as the small size of stream basins, historical processes and local levels of human occupation and development (Menezes et al. 2007).

Fish have been regarded as important bioindicators in river and stream systems since changes in their abundance and diversity often reflect the effects of a range of stress factors that influence the biotic integrity of the river (Faush et al. 1990). The advantages of fish as indicators of biological integrity are numerous (Karr 1981) but result mostly from their multiyear life span and mobility, as well as the range of trophic levels that they occupy. Therefore, they become good indicators of long-term and large-scale effects of human activities on habitat conditions.

Many of the fish inventories on Atlantic forests have been performed on southeastern streams, with very few studies north of the São Francisco River. This fact, added to the current state of fragmentation of northeastern forests, highlights the importance of studies about the ichthyofauna in northeastern Atlantic Forest streams, especially in conservation units that could act as indicators of the overall state of ecosystems as a whole (Kennard et al. 2006).

Thus, the present study aims at presenting a list of fish species for a conservation unit (REBIO Guaribas) that encompasses a fragment of Atlantic Forest (and its surroundings) in the northeast of Brazil, north of the São Francisco River; and report habitat characteristics for sites where the species were recorded.

Methods

Study site. The present study was performed at the Reserva Biológica Guaribas (REBIO Guaribas) in the State of Paraíba (Brazil) and its surrounding area. The REBIO has 4028 hectares divided into three fragments near the northern limits of occurrence of the Atlantic Forest (06°44′ S, 035°08′W). The 2 major fragments (Fig. 1), located in the municipality of Mamanguape, constitute a mosaic of semi-deciduous forests and savanna, which represent one of the last remainings of the Atlantic Forest in the region, harboring a range of rare, endemic and threatened species (MMA 2003). The REBIO Guaribas also represents one of the few fragments of Atlantic Forest in the state of Paraíba. Land use in the surrounding areas of the REBIO is represented by sugar-cane monocultures associated with the removal or management of the native vegetation for cattle growth and orchards. The hydrography of the study area is represented mostly by small drainage basins that encompass first and second order streams (Strahler 1964), tributaries of the Camaratuba River, that are feed by the many springs present in the region.

Data collection. Fish collections were performed bimonthly in 3 fixed stations along 2 streams (Caiana and Barro Branco streams) (Fig. 1), between February 2011 and January 2012. Another 11 sites were sampled within the REBIO and in its surrounding areas during the months of May, June and July 2013. Among the study streams, the Barro Branco stream is approximately 8.8 km long and its source is located in the REBIO with its upper stretches flowing within the conservation unit. The middle and lower stretches run through a mosaic of secondary Atlantic Forest, orchards and sugar-cane plantations, after it leaves the limits of the REBIO. This stream still presents riparian vegetation throughout most of its extent. The Caiana stream (approximately 9.8 km long) also has its source in the REBIO but most of it flows outside the conservation unit. The fixed stations in the Barro Branco stream are within the REBIO whereas the fixed stations of the Caiana stream are all outside the REBIO. The additional sites sampled are distributed across different habitat types (natural and managed) within the REBIO and outside its borders and represent streams, natural perennial and temporary pools, and artificial reservoirs (Fig. 1).

Environmental information was recorded at each sampling site. This was represented by site morphology: depth (m), width (m), and water velocity (m/s); water quality variables: dissolved oxygen (mg/L) and water temperature (°C); and the habitat structure: substrate composition and littoral underwater structures (see Medeiros et al. 2008). The substrate composition and littoral underwater structures were visually estimated as their proportional contribution (%) to the cover of the margins of each site across 9 to 12 survey points of 1 m^2. In each survey point the proportion of mud, sand, gravel and cobbles (sediment composition) and littoral and underwater structures (e.g., macrophytes, littoral grass, submerged terrestrial vegetation, overhanging terrestrial vegetation, leaf litter, algae and woody debris) were estimated visually (adapted from Pusey et al. 2004). Local morphology was evaluated by the average width and depth taken from 3 transects randomly placed in each site. Water velocity was estimated using the float method (Maitland 1990). Water quality variables were measured in the water surface using portable equipment (Hanna® HI 9828 meter). These data are presented to provide information on the environmental characteristics of sites where fish species occur.

Fish collection was performed during daylight hours based on Medeiros et al. (2010) using a short beach seine net (4 m long, 1.5 m high and 5 mm mesh), a long beach seine net (20 m long, 2 m high and 12 mm mesh), a cast net (2.4 m high and 12 mm mesh) and a dip net (50 cm wide and 5 mm mesh). Effort of capture was similar across sampling occasions and sites. Fish caught were

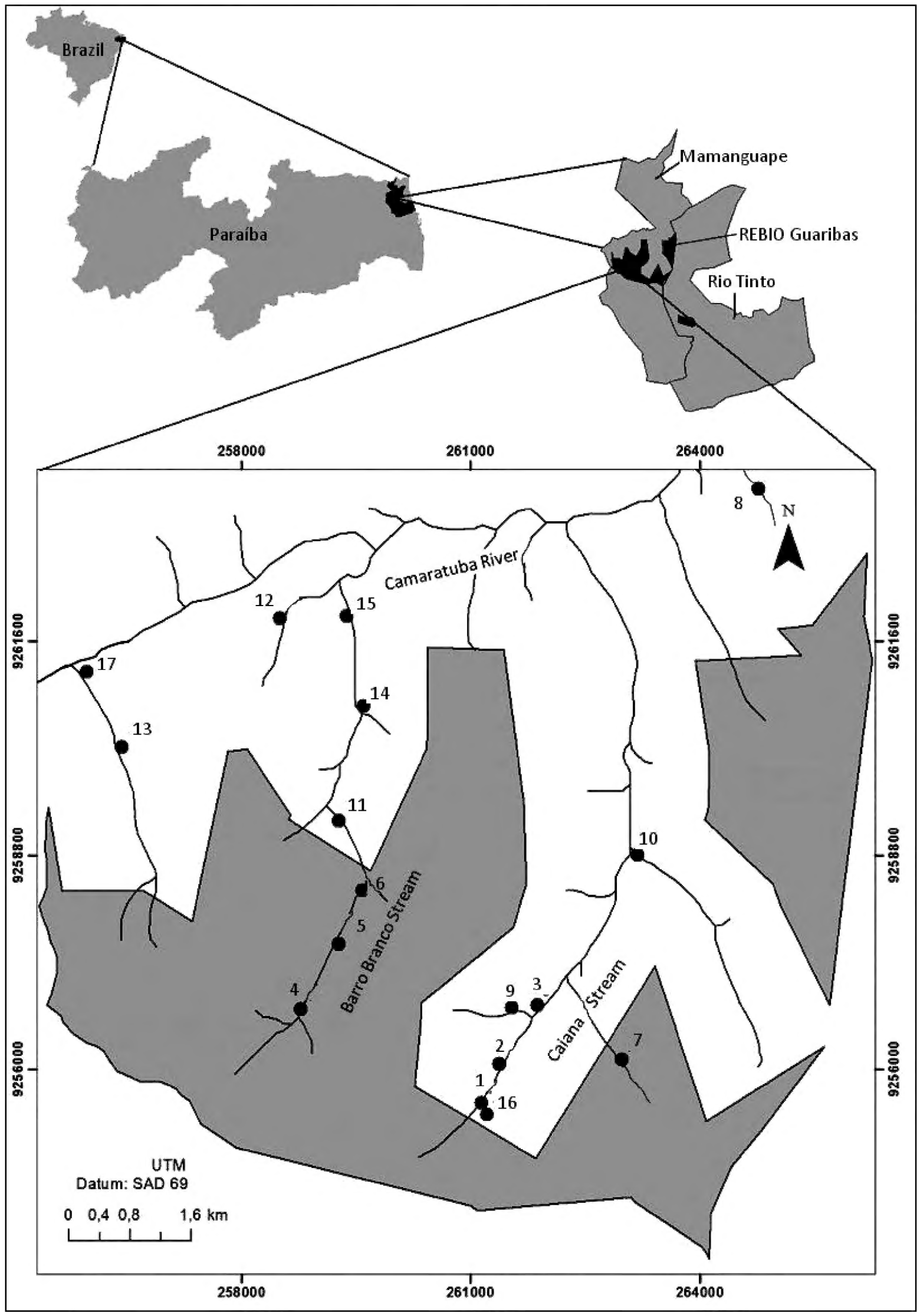

Figure 1. Study area showing the location of the REBIO Guaribas, major drainages and the sampling sites (Mamanguape, PB).

fixed in 10% formalin neutralized with sodium tetraborate and later transferred to 75% ethanol. The specimens were treated according to Brazilian rules of scientific curation (Malabarba and Reis 1987). Sorting and identification of specimens were carried out at the Ecology Laboratory of Universidade Estadual da Paraíba based on Britski et al. (1984) and Gomes-Filho (1999). Voucher specimens were deposited in the Ichthyological Collection of Universidade Federal da Paraíba (Appendix). Fish were collected under license 26163/1-4 IBAMA/SISBIO.

Data analysis. The species accumulation curve, Bray-Curtis distance curve (and their standard deviation) and the Jackknife estimators were calculated on PC-ORD 4.2 (McCune and Mefford 1999) to evaluate the adequacy of sample size. The distance curve represents the distance between a given cumulative sample and the centroid of the data set. It is expected that with each cumulative increase in sampling effort (meaning the cumulative increase in samples) the distance between the cumulative samples and the centroid decreases, that is, the more representative is a sample the lower the distance between

it and the dataset centroid (McCune and Grace 2002). For this analysis, the unit of effort was considered to be each sampling technique (seine nets, cast net and dip net) used at each sampling occasion, totaling 48 units.

Results

A total of 895 individuals were collected. Fish were distributed among 18 species, 7 families, and 5 orders (Table 1, Fig. 2). The most representative order was Characiformes with 12 species. Among the families recorded, Characidae was the richest with 8 species, followed by Cichlidae (3) and Erythrinidae (3). The other families were represented by only 1 species each (Fig. 2).

The most abundant species were *Hemigrammus unilineatus* (41% of the individuals), *Astyanax* aff. *bimaculatus* (22%), *Serrapinnus piaba* (16%), and *Hemigrammus marginatus* (9%). These species represented 88% of the individuals captured (Fig. 3). Among the species recorded, *Oreochromis niloticus* and *Poecilia reticulata* are introduced species. *Oreochromis niloticus* was recorded only in site 4 (that is, in the Barro Branco stream within the REBIO) and *P. reticulata* was recorded in sites 8 and 10 (in the surrounding areas outside the conservation unit). *Astyanax* aff. *bimaculatus* and *Hemigrammus unilineatus* were the most widespread species, being present in both study streams and in sites in the surrounding areas of the REBIO (Table 1). Among the sites surveyed within the REBIO 8 species were recorded, whereas 15 species were recorded outside the conservation unit. *Erythrinus erythrinus* and *Oreochromis niloticus* were recorded only within the REBIO and *Characidium bimaculatum*, *Cheirodon jaguaribensis*, *Hemigrammus rodwayi*, *Hoplerythrinus unitaeniatus*, *Hoplias malabari-*

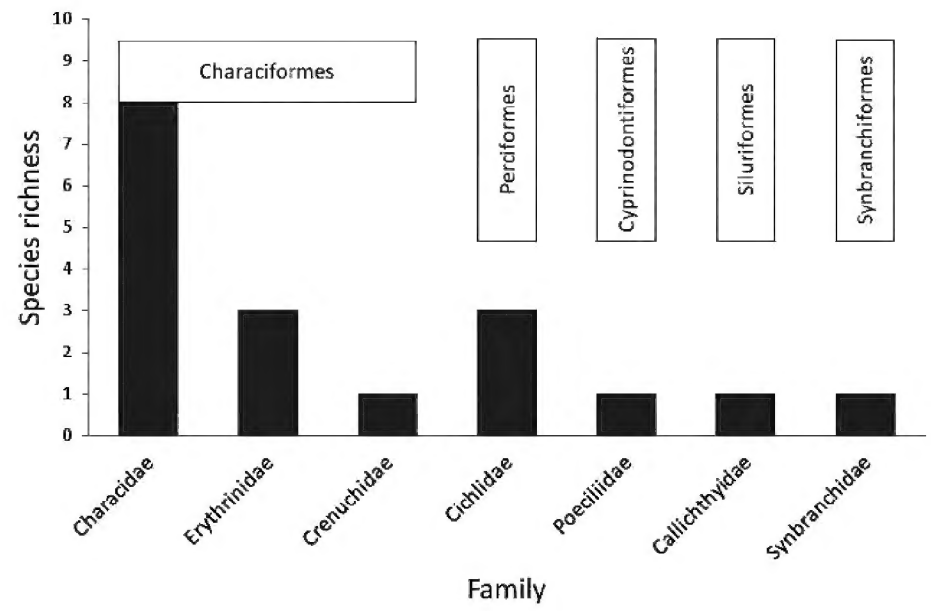

Figure 2. Species richness for family and order of fish from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB).

Table 1. Fish species from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB). Refer to Table 2 for site description. Sites 4–7 are located inside the REBIO. Taxonomic order according to Laan et al. (2014).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Order Characiformes																	
Family Erythrinidae																	
Hoplias malabaricus (Bloch, 1794)									X						X		
Erythrinus erythrinus (Bloch & Schneider, 1801)					X												
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)		X															
Family Characidae																	
Astyanax aff. *bimaculatus* (Linnaeus, 1758)	X	X	X			X		X	X			X	X	X	X		X
Astyanax aff. *fasciatus* (Cuvier, 1819)					X	X		X	X	X							X
Cheirodon jaguaribensis Fowler, 1941												X					
Hemigrammus rodwayi Durbin, 1909										X							
Hemigrammus marginatus Ellis, 1911	X	X	X	X						X			X				
Hemigrammus unilineatus (Gill, 1858)	X	X	X	X	X	X	X		X	X	X						
Serrapinnus piaba (Lutken, 1875)	X	X	X							X		X	X		X		
Serrapinnus heterodon (Eigenmann, 1915)												X					X
Family Crenuchidae																	
Characidium bimaculatum Fowler, 1941	X												X				
Order Siluriformes																	
Family Callichthyidae																	
Megalechis thorocata (Valenciennes, 1840)														X			
Order Cyprinodontiformes																	
Family Poeciliidae																	
Poecilia reticulata Peters, 1860 *								X		X							
Order Synbranchiformes																	
Family Synbranchidae																	
Synbranchus marmoratus Bloch,1785											X					X	
Order Perciformes																	
Family Cichlidae																	
Cichlasoma orientale Kullander, 1983				X		X	X	X	X			X		X			
Crenicichla menezesi Ploeg, 1991	X	X	X		X	X											
Oreochromis niloticus (Linnaeus, 1758) *				X													
Total of species	6	6	5	4	4	5	2	4	5	6	2	5	4	3	3	1	3

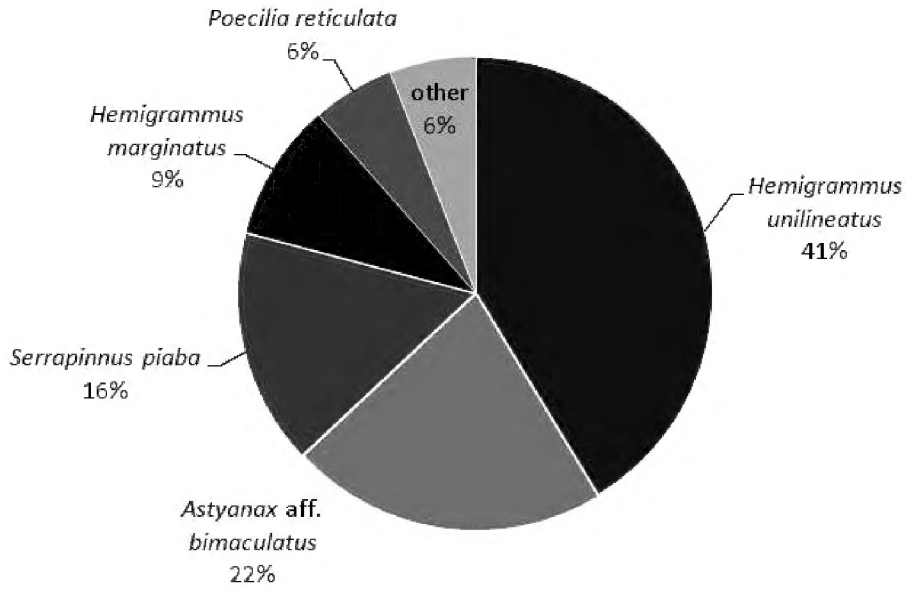

Figure 3. Abundance of fish species from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB).

cus, *Megalechis thorocata*, *Poecilia reticulata*, *Serrapinus heterodon*, *Serrapinnus piaba*, and *S. marmoratus* were recorded only outside the REBIO (Fig. 4).

The environmental variables showed that the study sites vary in morphometry, mostly with regard to their size. For instance, the coefficient of variation (CV) for width was 240% (Table 2). Maximum marginal depth was generally low with an average of 55 cm (CV=39%). Water flow was observed mostly in stream sites, both within and outside the REBIO, ranging between 0.08 and 0.47 m/s. The sites in the Barro Branco (within the REBIO) and Caiana streams showed highly oxygenated water (6.4–10.6 mg/L) compared with the remaining sites (0.2–3.8 mg/L). Water temperature ranged between 23.9 and 34.9 °C. Substrate of the study sites was composed mostly of mud and sand, whereas the habitat was diverse mostly in the Caiana and Barro Branco streams (sites 1, 2, 3, 4, 5 and 6, Table 3) with a range of underwater and marginal structures such as macrophytes, overhanging vegetation, leaf litter, tree roots, and woody debris (Table 3).

Species accumulation and distance curves (Fig. 5) show that the number of species increases with the cumulative increase in units per effort of capture. Overall, 36 units of effort will capture about 16 species (90% of the total richness), with more samples yielding relatively small increases in the number of species. Similarly, 36 units of effort will yield a Bray-Curtis distance of 0.1 (10%), measured between the centroid of the 36 cumulative units and the centroid of the whole dataset. These results mean that further increases in capture per unit of effort will render the sample only slightly more similar to the whole dataset (based on both richness and species composition). This indicates that the sampling effort was representative, with at least 90% of the species being captured at 75% of the effort employed (36 units of capture effort). Nonetheless, both accumulation and distance curves did not show clear tendency to stabilize towards the maximum number of units per capture effort (48). Also, the expected diversity was greater than the number of species observed, as demonstrated by the Jackknife estimators (23.9 species for the first-order Jackknife and 25.9 species for the second-order Jackknife), compared to the total of 18 observed species. This indicates a high diversity of species even after the capture per unit of effort employed. Furthermore, the Bray-Curtis similarity

Table 2. Environmental variables (± SD) measured in the sampling sites from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB). n.m. = not measured. RB = within the REBIO. SA = surrounding areas. CV = coefficient of variation.

Site	Description	Location	Coordinate (UTM)	Site morphology			Water quality	
				Width (m)	Marginal depth (m)	Water velocity (m/s)	Dissolved oxygen (mg/L)	Temperature (°C)
1	Stream (Caiana)	SA	261141X 925556Y	1.27 (±20.42)	0.33 (±18.49)	0.09 (±0.04)	7.60 (±4.33)	26.10 (±0.92)
2	Stream (Caiana)	SA	261375X 9256065Y	1.21 (±17.73)	0.32 (±15.58)	0.34 (±0.06)	6.70 (±2.29)	27.30 (±1.98)
3	Stream (Caiana)	SA	261869X 9256841Y	1.54 (±34.86)	0.24 (±13.41)	0.33 (±0.08)	10.60 (±6.14)	27.90 (±1.84)
4	Stream pool (Barro Branco)	RB	258776X 9256785Y	1.15 (±27.43)	0.19 (±9.46)	0.25 (±0.04)	7.80 (±3.71)	26.10 (±1,47)
5	Stream (Barro Branco)	RB	259265X 9257643Y	1.80 (±29.68)	0.24 (±11.49)	0.15 (±0.03)	7.80 (±2.61)	25.10 (±1.64)
6	Stream (Barro Branco)	RB	259571X 9258342Y	1.40 (±20.78)	0.25 (±11.94)	0.21 (±0.03)	6.40 (±1.65)	26.10 (±2.22)
7	Stream pool	RB	262975X 9256127Y	9.00	0.26 (±5.10)	0	1.40	25.30
8	Stream pool	SA	264762X 9263598Y	5.30	0.21 (±5.19)	0.08 (±0.97)	1.10	25.80
9	Stream pool	SA	261534X 9256802Y	3.50	0.20 (±9.76)	0.14 (±0.67)	1.60	25.70
10	Stream pool	SA	263181X 9258808Y	4.30	0.29 (±13.89)	0.47 (±0.23)	2.30	n.m.
11	Stream pool (Barro Branco)	SA	259274X 9259255Y	4.00	0.22 (±9.29)	0	1.0	25.00
12	Artificial reservoir	SA	258497X 9261907Y	115.00	0.10 (±34.14)	0	3.70	29.00
13	Stream	SA	256427X 9260219Y	7.60	0.11 (±3.08)	0.40 (±0.26)	2.10	23.90
14	Temporary pool (Barro Branco)	SA	259594X 9260758Y	n.m.	0.18 (±8.38)	0	1.80	34.70
15	Stream pool (Barro Branco)	SA	259369X 9261938Y	5.80	0.55 (±28.64)	0	3.80	29.00
16	Temporary pool	SA	261207X 9255401Y	11.70	0.25 (±11.28)	0	1.80	34.90
17	Stream	SA	255969 X 9261200 Y	5.00	0.28 (±13.5)	0.15 (±0.80)	0.20	25.30
CV				240%	39%	99%	77%	11%

Table 3. Habitat structure (± SD) measured in the sampling sites from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB). Refer to Table 2 for site description.

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Substrate composition																	
Mud	100 (±0)	93 (±11.66)	0.07 (±0.13)	92 (±16)	29.30 (±13.06)	100 (±0)	100 (±0)	1 (±0)	2 (±2,16)	3,67 (±1.89)	8.33 (±2.36)	0	50 (±0)	95 (±0)	95 (±0)	90 (±0)	1 (±0)
Sand	0	7 (±11.66)	99,90 (±48,94)	8 (±16)	70.53 (±13.11)	0	0	79 (±0)	64 (±45.26)	95 (±0)	91.70 (±2.36)	100 (±0)	19.30 (±21.93)	5 (±0)	5 (±0)	10 (±0)	99 (±0)
Gravel	0	0	0,07 (±0,13)	0	0.83 (±0.27)	0	0	15 (±0)	0,7 (±0.94)	6 (±0)	0	0	1.33 (±1.11)	0	0	0	0
Cobbles	0	0	0	0	0	0	0	5 (±0)	0	0	0	0	3 (±0.94)	0	0	0	0
Underwater and littoral structures																	
Aquatic macrophytes	5.73 (±2.28)	0.40 (±0.33)	0	2.09 (±2.31)	6.47 (±2.64)	6.27 (±3.26)	15 (±0)	2.33 (±0.94)	11.22 (±5.37)	15.43 (±7.23)	50 (±2.12)	0.33 (±0.47)	30 (±20)	1 (±0)	50 (±0)	5 (±0)	12 (±8.04)
Littoral grass	2.07 (±1.07)	0.27 (±0.39)	0.07 (±0.13)	0.40 (±0.49)	3.20 (±1.82)	0.93 (±0.33)	3 (±0)	15 (±0)	5.30 (±3.30)	10 (±0)	6.70 (±4.71)	16.70 (±23.57)	5 (±0)	40 (±0)	15 (±0)	10 (±0)	3 (±0)
Submerged vegetation	0.94 (±0.93)	1.67 (±0)	0.50 (±1.02)	2.72 (±0.71)	2.22 (±1.94)	1.83 (±2.02)	3 (±0)	0	0	0	1 (±1.41)	0	0	60 (±0)	1 (±1.41)	3 (±0)	1 (±0)
Overhanging vegetation	67.78 (±32.05)	53.33 (±24.51)	69.94 (±32.82)	69.17 (±30.97)	65.83 (±32.22)	73 (±32.74)	85 (±0)	0	1 (±1.41)	0	26.70 (±37.71)	0	0	0	10 (±14.4)	0	10 (±0)
Submerged leaf liter	10.70 (±5.85)	5.39 (±6.02)	3.32 (±1.74)	13.39 (±7.67)	8.61 (±5.11)	14.28 (±7.15)	80 (±0)	0	0	2.33 (±0.94)	1.67 (±0.94)	0	0	0	1 (±0)	0	0
Algae	0.78 (±0.71)	0.39 (±0.56)	0	0.06 (±0.12)	0	0	0	1 (±0)	12.03 (±3.16)	2.67 (±1.89)	0	0	0	0	5 (±0)	0	3 (±0)
Root masses	1.78 (±1.84)	3.22 (±1.83)	5.33 (±2.90)	2.61 (±1.21)	3.56 (±2.21)	3.39 (±1.70)	6 (±0)	0	0	0	2 (±1.41)	0	0	0	0	0	0
Underwater aquatic debris	12.27 (±4.05)	5.83 (±2.59)	10.78 (±4.32)	14.56 (±4.01)	8.05 (±2.16)	9.67 (±2.75)	25 (±0)	5 (±0)	3 (±0)	6 (±2.16)	5.33 (±0.47)	6.67 (±9.43)	3 (±0)	0	5 (±0)	4 (±0)	1 (±0)

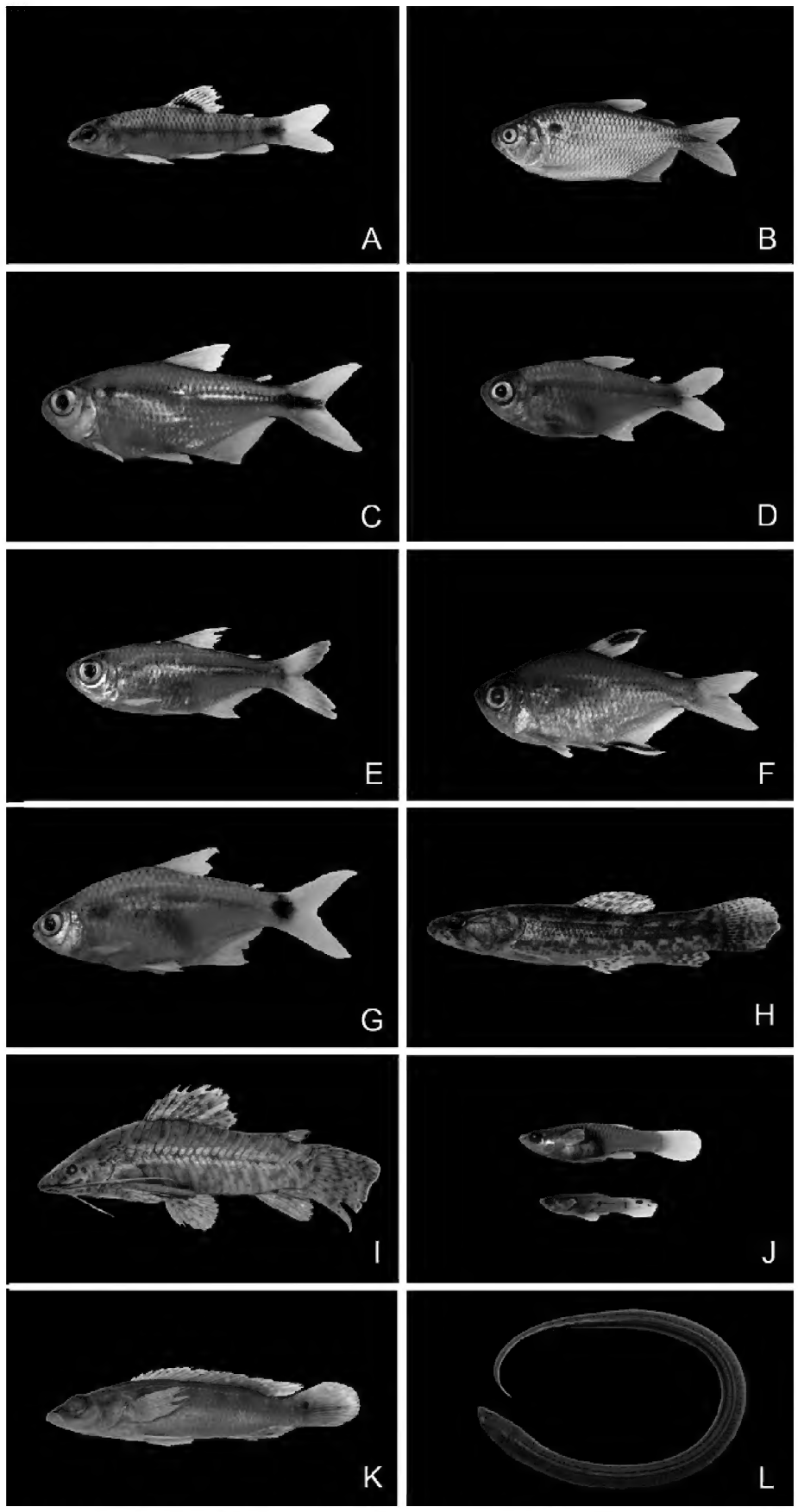

Figure 4. Main species of freshwater fish from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB): A. *Characidium bimaculatum*; B. *Astyanax* aff. *bimaculatus*; C. *Astyanax* aff. *fasciatus*; D. *Cheirodon jaguaribensis*; E. *Hemigrammus marginatus*; F. *Hemigrammus unilineatus*; G. *Serrapinnus piaba*; H. *Hoplias malabaricus*; I. *Megalechis thorocata*; J. *Poecilia reticulata*; K. *Crenicichla menezesi*; L. *Synbranchus marmoratus*.

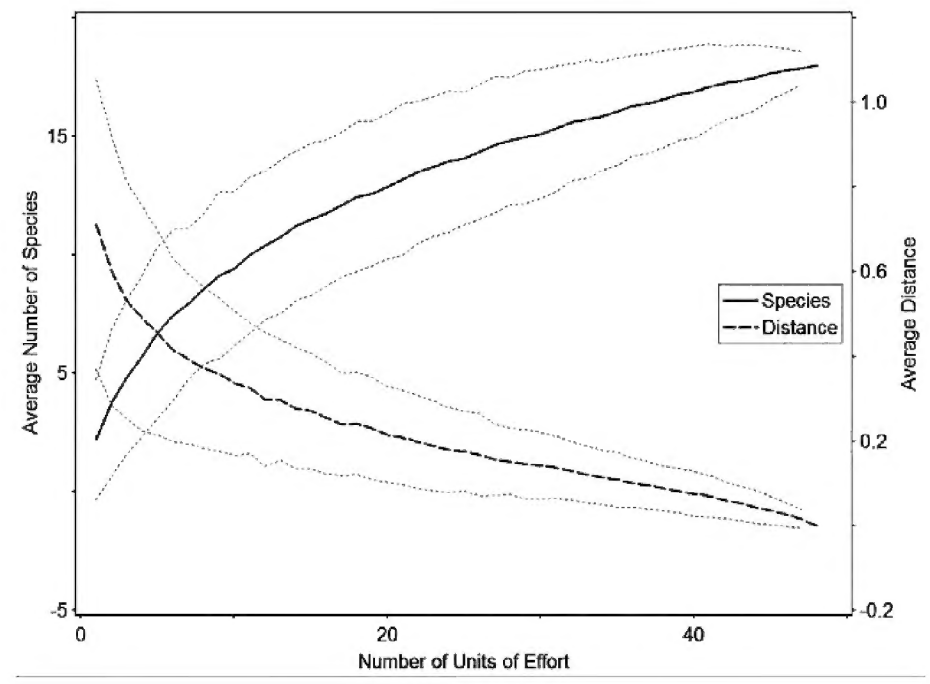

Figure 5. Accumulation and distance curves (± SD) used to assess sample adequacy of capture effort of fish from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB).

(based on species composition and abundance) measured between the units of effort and the total of species sampled, shows that the cumulative similarity decreases as further effort of capture is employed. This indicates that the effort of capture employed, regarding the species composition, was gradually incorporating new species and decreasing its distance to the whole of species.

Discussion

The ichthyofauna observed in the REBIO Guaribas and surrounding areas is relatively rich (18 species) when compared to other studies for coastal drainages in northeastern Brazil, in the domain of both semi-arid and tropical climates. Studies report a total of 44 species for the state of Paraíba, with neighboring states presenting similar richness (e.g., Rio Grande do Norte, 36 freshwater species). Surveys on river basins that flow through Atlantic Forest areas north of the São Francisco River also report diversities not considerably greater than the study area, when river length and basin area are taken into account. In the Gramame River basin (Paraíba), 22 freshwater species were reported (Torelli et al. 1997, Gomes-Filho and Rosa 2001). Rosa and Groth (2004) reported 27 species of fish for forest areas in the domains of Atlantic Forest and Caatinga in the states of Pernambuco and Paraíba. Ramos et al. (2005) reported 22 species for the neighboring basin of the Curimataú River (Paraíba and Rio Grande do Norte), which flows partially through Caatinga and through Atlantic Forest. Paiva et al. (2014) recorded 22 species of which 13 are from freshwater in the small coastal basin of the river Pratagi in the domains of Atlantic Forest (Rio Grande do Norte). Therefore, taking into consideration that these river systems range between approximately 180 km (Curimataú River) to 10 km (Pratagi River) in length, and for instance the Barro Branco stream has approximately 9 km in length (with 12 species, 18 overall for the study area), the diversity reported in the present study is considerable.

Besides the list of species presented, this study reports habitat characteristics for sites where the species were recorded. The physical structure of the habitat and water quality variables must be considered when evaluating ecosystem health in conservation units, since these agents affect the structure and composition of conspicuous aquatic organisms, such as fish (Gorman and Karr 1978, Angermeier and Karr 1983). Most of the study sites represent Atlantic Forest streams with different levels of degradation and riparian vegetation modification, therefore, present habitat characteristics associated with small forested streams (Santos and Esteves 2014). In the present study, water velocity and dissolved oxygen were important attributes that varied considerably across study sites and have the potential to influence the fish fauna

(Castro et al. 2004). Menezes et al. (2007) pointed out that fish diversity in streams is subject to the management of the riparian zone. Given that land use and vegetal cover removal change the composition of underwater structures, as well as, physical and chemical water variables, these attributes must be monitored in order to assess their effects on fish diversity.

The record of *Hemigrammus unilineatus* and *Hemigrammus rodwayi* is of interest for studies of the past connections between the Atlantic and Amazonian forests, since *Hemigrammus unilineatus* is a species with its distribution reported for streams in Trinidad, Venezuela, Guiana, Suriname, French Guiana, Guaporé and Amazonas (Reis et al. 2003, Eschmeyer 2015) and also in northeastern Brazil streams that flow through the Atlantic Forest (Buckup et al. 2007, Menezes et al. 2007). *Hemigrammus rodwayi* has been reported for streams in Guiana, Suriname, French Guiana and the Amazon basin (Reis et al. 2003, Buckup et al. 2007) with few reported records for the northeastern Brazil (Teixeira et al. 2017).

Species of the genus *Hemigrammus*, are small-bodied and habitat-specific. The predominance of small-bodied species in small drainages is a common feature in South American fishes (Castro 1999). The small size of the study streams may also explain the low abundances and restrict distribution of the study species across the study sites. Since these are first order streams that feed a much larger river (the Camaratuba River), the study species will have, as a result, naturally low densities and occupy specific microhabitats (see Novotný and Basset 2000 for insight). With that in mind, the predominance of Characiformes in the ichthyofauna of the study sites is expected based on other studies for the region and for the Neotropics (Reis et al. 2003, Rosa et al. 2003, Paiva et al. 2014, Ramos et al. 2014).

Two non-native species were recorded in the study sites: *Poecilia reticulata* and *Oreochromis niloticus*. Although this is an undesirable finding, these are common species in the northeastern basins (Leão et al. 2011, Levis et al. 2013). Nonetheless, the presence of *O. niloticus* in a site inside the conservation unit suggests that this species may have spread from local reservoirs to the conservation unit and demands a more detailed evaluation of its distribution throughout the local streams and its monitoring across sites within the REBIO. Given the history of species introductions in Brazil's northeastern drainages (Gurgel and Oliveira 1987) and the fact that other neighboring drainages have higher rates of species of fish introduced, for instance 5 introduced species are reported for the Paraíba do Norte River (Montenegro et al. 2011), the presence of *P. reticulata* and *O. niloticus* becomes a concern and their distribution should be evaluated and monitored. This is aggravated by the fact that *O. niloticus* feeds on food items from the basis of the trophic web, and is associated with a large feeding plasticity, tolerance to environmental change and efficient reproductive behavior (with parental care, high growth rates and short reproductive maturity) (Attayde et al. 2007). *Poecilia reticulata* is also a successful invasive species well adapted to human effects on freshwaters, tolerant to salinity and hypoxia and opportunist behavior (Lemes and Garutti 2002, Casatti et al. 2009). These are advantageous characteristics of both species over native ones and make them efficient invasive species and a threat to the natural local populations.

Associated with the small size of most fish species inhabiting small drainages are their relatively high endemism and preference for specific microhabitats (Castro 1999). Adding the constant threat from invasive species, these factors highlight the need for the establishment of conservation and management policies for small streams that flow through areas of Atlantic Forest. Since, in these cases, endemism is likely to result from the limited locomotion ability of small-size species, which do not undertake long migrations, they tend to become isolated. This relative isolation has been argued to be a facilitating agent for allopatric speciation (Castro 1999). In conclusion, the small size of most fish species inhabiting small Atlantic Forest streams and its associated limited spatial distribution, their relatively high endemism, preference for specific microhabitats and the threat of invasive species makes Atlantic Forest fish species highly vulnerable to environmental degradation and even small areas of conservation units become important in their conservation and diversity maintenance.

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Authors' Contributions

All authors participated in the data collection and wrote the text. RSDG and GLAL identified the species, TPAR confirmed the identifications.

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Appendix

Voucher specimens of freshwater fish from the Reserva Biológica Guaribas and its surrounding areas (Mamanguape, PB).

***Astyanax* aff. *bimaculatus*:** UFPB 9614, UFPB 9625, UFPB 9626, UFPB 9630, UFPB 9631, UFPB 9632, UFPB 9642, UFPB 9650, UFPB 9654, UFPB 9662, UFPB 9663, UFPB 9664, UFPB 9665, UFPB 9666, UFPB 9667, UFPB 9669, UFPB 9670, UFPB 9675, UFPB 9678.

***Astyanax* aff. *fasciatus*:** UFPB 9656, UFPB 9676, UFPB 9681, UFPB 9682, UFPB 9740, UFPB 9748.

***Characidium bimaculatum*:** UFPB 9683, UFPB 9741.

***Cheirodon jaguaribensis*:** UFPB 9660.

***Cichlasoma orientale*:** UFPB 9628, UFPB 9643, UFPB 9647, UFPB 9648, UFPB 9649, UFPB 9651, UFPB 9653, UFPB 9679, UFPB 9747.

***Crenicichla menezesi*:** UFPB 9609, UFPB 9617, UFPB 9624, UFPB 9641, UFPB 9673, UFPB 9744.

***Oreochromis niloticus*:** UFPB 9748. ***Erytrinus erythrinus*:** UFPB 9749.

***Hemigrammus marginatus*:** UFPB 9627, UFPB 9632, UFPB 9644, UFPB 9677, UFPB 9745, UFPB 9746.

***Hemigrammus unilinetaus*:** UFPB 9606, UFPB 9607, UFPB 9608, UFPB 9610, UFPB 9611, UFPB 9612, UFPB 9613, UFPB 9615, UFPB 9616, UFPB 9618, UFPB 9619, UFPB 9620, UFPB 9621, UFPB 9622, UFPB 9623, UFPB 9629, UFPB 9634, UFPB 9635, UFPB 9636, UFPB 9637, UFPB 9638, UFPB 9639, UFPB 9640, UFPB 9645, UFPB 9661, UFPB 9668, UFPB 9671, UFPB 9674, UFPB 9743.

***Hemigrammus rodwayi*:** UFPB 9736, UFPB 9751.

***Hoplerythrinus unitaeniatus*:** UFPB 9750.

***Hoplias malabaricus*:** UFPB 9652, UFPB 9658.

***Megalechis thorocata*:** UFPB 9657.

***Poecilia reticulata*:** UFPB 9646, UFPB 9659, UFPB 9680.

***Serrapinnus heterodon*:** UFPB 9742.

***Serrapinnus piaba*:** UFPB 9728, UFPB 9729, UFPB 9730, UFPB 9731, UFPB 9732, UFPB 9733, UFPB 9734, UFPB 9735, UFPB 9737, UFPB 9738, UFPB 9739.

***Synbranchus marmoratus*:** UFPB 9655, UFPB 9672.